

COLD LEAK PROBLEMS RELATED TO HELICOFLEX GASKETS AND RECENT RESULTS FORM THE S-DALINAC*

R. Eichhorn[#], A. Araz, J. Conrad, F. Hug, A. Kuhl, C. Liebig, M. Konrad, T. Kuerzeder, F. Schlender and S. Sievers

S-DALINAC, Institut fuer Kernphysik, TU-Darmstadt, D-64293 Darmstadt, Germany

Abstract

During the last two years, the S-DALINAC operation suffered severely from cold leaks: They were hard to locate, sometimes vanished without any obvious reason or showed up again depending on the thermo-cycle. Finally, the gaskets sealing the cavity against the helium reservoir were found to be the reason for this behaviour. We will report on the findings itself, the systematic becoming obvious and the solution chosen to ensure tightness in the future.

Moreover, we will give a status report on two ongoing projects in Darmstadt: the injector upgrade where a new cryo-module is built, housing two cavities and improved power couplers and the cavity performance improvement by heat treatment at 850 C in an UHV oven.

INTRODUCTION

The superconducting Darmstadt electron linear accelerator S-DALINAC was put into operation in 1987. It consists of ten superconducting 20 cell niobium cavities, operated at 2 K at a frequency of 2.9975 GHz. With a design accelerating gradient of 5 MV/m and a design quality factor of $3 \cdot 10^9$ in cw operation, the final energy of the machine is 130 MeV which is reached when the beam is recirculated twice [1]. The layout of the S-DALINAC is shown in fig. 1.

The first set of cavities was built in the 80's at Interatom using low RRR material, so the observed performance regarding the gradient and the quality factor was rather poor [2]. Accordingly, a second set of cavities was ordered in the 90's made from RRR 300 material. These cavities, welded at Dornier, are used since then. All of them reach the design gradient, some exceeding it by more than 50% [3]. In the original design, an antenna coupler was mounted to the cavity sealing the beam vacuum against the helium with an Indium wire.

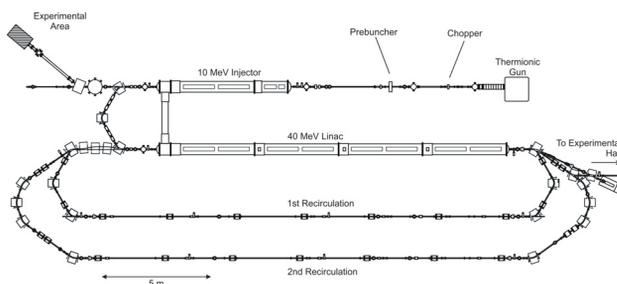


Figure 1: Floor plan of the S-DALINAC.

Later on, new power couplers were designed reducing the transversal kick to the beam dramatically and providing variable coupling [4]. In this design process, the Indium joint was replaced by a HELICOFLEX® gasket which now, after 10 years of operation with many thermo-cycles and mounting/ dismantling procedures developed hard to locate cold leaks.

COLD LEAK PROBLEMS

Over the past two years, several cold leaks developed, degrading the cavity performance and disrupting the accelerator operation. After several time consuming investigations the reason for these cold leaks could be determined: The HELICOFLEX® gasket used to seal the cavity flange against the coupler (see fig. 2) became untight. This was first observed after an insitu-baking procedure (heating the cavity to 150 C) followed by an immediate cool-down to 2 K. Later on, cold leaks also developed without prior baking.

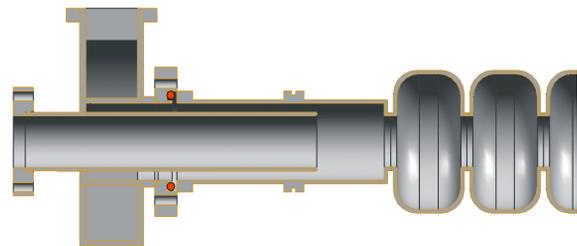


Figure 2: Cross section of the coupler to cavity transition. The HELICOFLEX® gasket used is marked red.

After checking all parameters to lie within specifications the reason for this was localized: the HELICOFLEX® gasket made out of aluminium was hard enough to cave the flat cavity flange (made out of RRR30 Niobium) after many years of operation, some 50 thermal cycles and approximately 10 replacements of the gaskets. As the tightness of this gasket is ensured by pressing it to a nominal thickness which is ensured by a nose-piece in the coupler flange, the score mark in the cavity flange reduces the compression of the gasket and thus explains the failure in tight sealing. Some of the flanges had rather deep imprints of the gaskets. Some of them could be seen directly, for example as show in fig. 3.

Other cavity flanges had now visible traces. Finally, the surface profiles of all cavity flanges were measured with a flush pin gauge. 12 radial positions were measured, starting form the outer rim of the cavity flange in steps of 500 μm . The data were taken for 8 azimuthal positions (nominated N for the up-position, S for down position etc.

*Work supported by the DFG through SFB 634

[#]eichhorn@ikp.tu-darmstadt.de

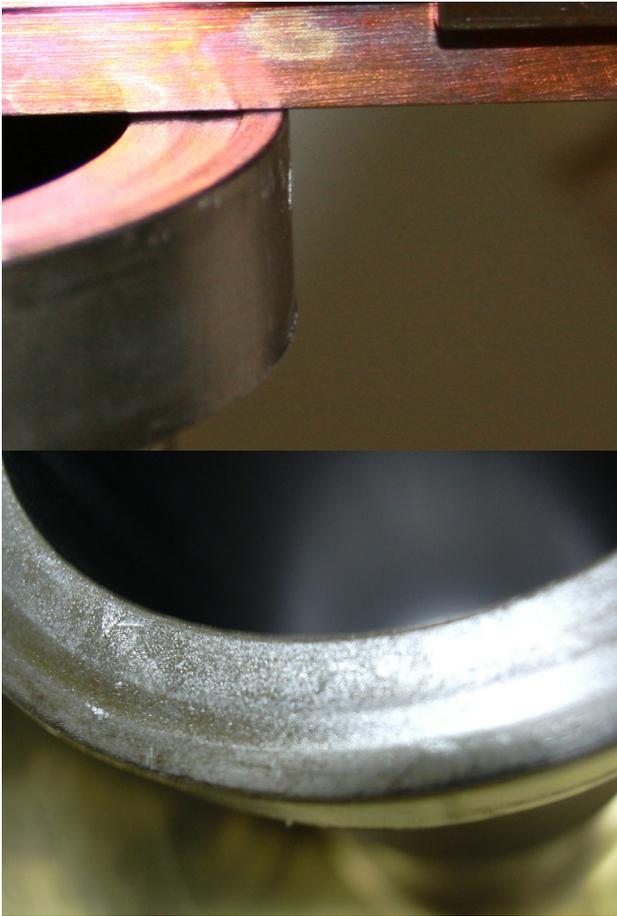


Figure 3: Picture of the cavity flange (DO2 in) displaying an obvious imprint of the gasket. The measured profile is shown in fig.4.

when looking onto the flange). The profile for the flange of cavity DO2 (pictured in fig. 3) is shown in fig. 4. In addition to the gasket imprint grooving approx. 150 μm into the flange, a somehow linear radial change was measured, indicating a twist of the whole flange, eventually caused by an improper mounting procedure.

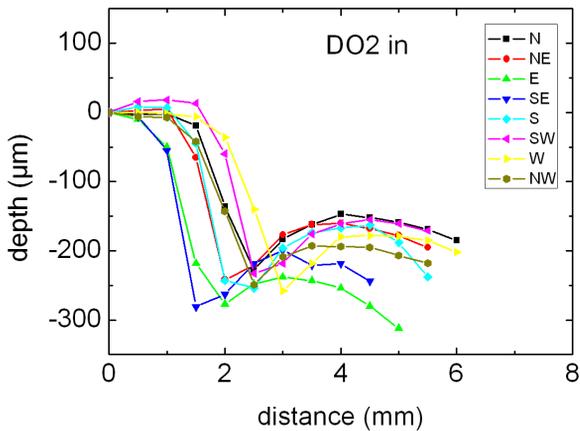


Figure 4: Measured profile of the input coupler flange of cavity DO2, displaying a strong imprint of the gasket (approx. 150 μm) plus another 100 μm from a flange twist.

03 Operating experience with SRF accelerators

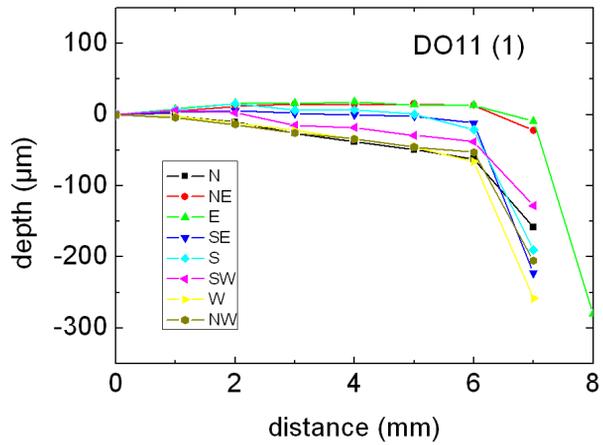


Figure 5: Measured profile of cavity DO11 being still reasonable flat.

In contrast to the findings on cavity DO2, the flange profile of cavity DO11, as shown in fig. 5, is rather undisturbed. By measuring all 16 flanges of the linac cavities, almost every profile between the two extremes in figures 4 and 5 was found: the depth of the imprint groove was in the range from 0 to less than 200 μm . This value seems to be

- independent from the number of thermo-cycles the transition goes thru but
- dependent on the number of mounting/ dismounting procedures (where the gasket is replaced by a new one).

Even so quantitative figures could not be traced back, it seems to be plausible that every mounting/ dismounting procedure engraves or deepens the groove by about 10-15 μm , as the newly inserted gasket is compressed for the first time.

As a consequence from the cold leakage, all HELICOFLEX® gaskets had to be replaced by gaskets with overmeasure (by adding the depths of the score to the gasket thickness- 200 μm), not solving the principle problem but ensuring tightness without machining the ultraclean surface of the cavity or the coupler.

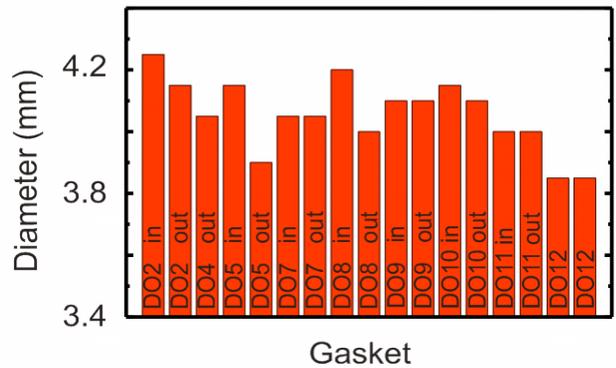


Figure 6: Histogram of the final thickness of the replaced gaskets. The nominal value in the mounted position is 3.5 mm but no figures for the decompression during dismounting are given by the supplier.

Finally, the thickness of all gaskets being replaced was measured, leading to the results shown in fig. 6. The variation found on the flanges becomes obvious again: the groove of the input coupler of cavity DO2 was 150-200 μm deep and the gasket was less compressed (by approx. 200 μm compared to the gaskets of cavity DO11, having no imprint on the flange).

Meanwhile, the gaskets were replaced as described above. So far, no cold leakage has been observed.

NEW INJECTOR MODULE

The S-DALINAC uses cryostat-modules with two cavities per module. Each cavity has an RF input coupler, which is capable of a maximum power of 500 W. Assuming a 5 MV/m gradient the beam current is limited to 60 μA for the injector and 20 μA for the main linac, which might be higher for lower beam energies. For future astrophysical experiments behind the injector, beam currents of 150 μA and above as well as energies up to 14 MeV are demanded.

The first step was to build a new power coupler which is capable of providing the necessary rf power of up to 2 kW to the cavity. The design feature of the old couplers, namely minimized transversal fields (less than -40 dB on the beam axis), was kept by the new couplers [5].

The whole coupler was made out of bulk niobium. The fabrication of the couplers including the EB-welding was done by the FZ Juelich. This new coupler has a WR-284 waveguide transition (cross area $72 \times 34 \text{ mm}^2$), which has to pass through the cryo-module. Accordingly the existing cryostat-module has to be modified.

Figure 7 shows the 3-D view of the design. The cavities together with their tuners and the couplers are located inside the helium vessel. During 2 K operation the vacuum inside the beamline is about 10^{-8} mbar, while the pressure in the liquid helium is at 35 mbar. Between the helium vessel and the outer vessel a cylinder of aluminium is cooled by liquid nitrogen. The insulating vacuum of 10^{-5} mbar and some 20 layers of super-insulation ensure a minimum heat transfer.

The design issue was to accommodate the increased size of the rf waveguide (compared to the small coaxial line used by the old couplers), while keeping all sections leak-tight and still mountable. Furthermore, the vacuum forces on the materials had to be compensated; especially the transition between the waveguide and the new coupler must be force-free. This was not critical in the old design, where the coax-to-coax coupler was supported by a shell out of stainless steel around it. The rectangular waveguide further one needs a bellow to compensate the uncertainties in position and angle in the transition line. This part is still vacant- so far no supplier could be contracted. More details on the new injector module can be found in [6].

ONGOING ACTIVITIES

Cavity Firing

As reported on the last workshop [7], all cavities, as soon as they are accessible, are undergoing a high temperature vacuum firing. This procedure is applied to stress anneal the niobium and to remove hydrogen from the material inoculating cavities against the "Q disease"

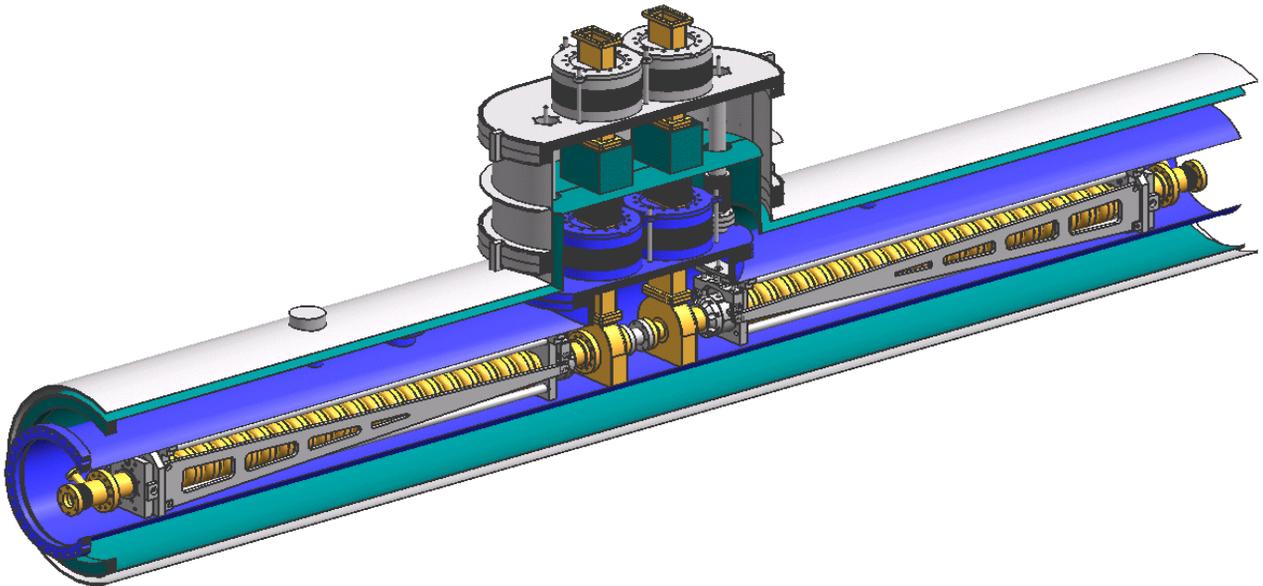


Figure 7: 3-D Design of the new injector module. Inside the helium vessel RF input and output couplers, together with the 20 cell cavities and their frequency tuners are shown. These inner parts are surrounded by a thermal shielding, cooled with liquid nitrogen, made out of aluminium. The outer pressure vessel will be stainless. In the center, the waveguides and their transitions through the different vacuum/ pressure stages in the so-called tower section are shown. For a better view the carriage which supports the tuners, the beam line, several lines for nitrogen and helium, the magnetic shielding and the MLI are not shown.

during their operation. So far, 8 out of the 14 cavities have been fired in the furnace. All of them showed a hydrogen contamination which could be reduced significantly. However, after these cavities were put back into operation inside the accelerator, the quality factor was found to be enhanced, but none-the-less below the envisaged $3 \cdot 10^9$. Therefore, other sources of Q-degradation are under investigation, for example the magnetic shielding.

Improved Magnetic Shielding

Due to the complex geometry of the frequency tuner and the necessary penetrations for the beam pipe and the rf power lines, an optimal magnetic shielding is hard to design. By now, different design options are still under optimization. One idea is to add an additional layer of 0.2 mm CRYOPERM®, another is to test piezoelectric actuators [8] and replace our actual magneto restrictive elements in the cavity tuner. Figure 8 shows those improvements in the actual shielding by adding more layers of CRYOPERM®. The up-to-date tests showed an average magnetic flux strength of $6.3 \mu\text{T}$ is possible. Although that means an improvement by a factor of 2, compared to the old setup, reaching the design quality factor of a cavity requires a field less than $3 \mu\text{T}$. Currently, an active compensation scheme is tested which seems to meet this requirement.

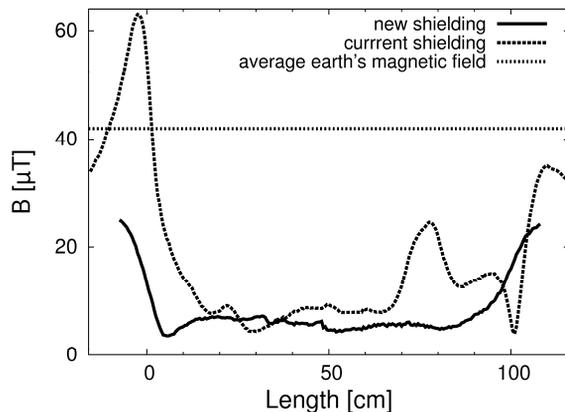


Figure 8: The absolute magnetic flux strength at the cavity location for the old magnetic shielding and the new one, compared to the average earth magnetic field of $42 \mu\text{T}$. The cavity is placed between 0 and 100 cm, thus the average magnetic field strength in that region is $13.8 \mu\text{T}$ for the old setup and $6.3 \mu\text{T}$ for the new setup.

SUMMARY AND OUTLOOK

During the last two years, the operation of the S-DALINAC suffered from leakage problems, which could be located finally to be the HELICOFLEX® gaskets that had engraved an imprint into the niobium flange of the cavity. By replacing the gaskets by similar ones with increased thickness, the tightness could be ensured again.

The improvement of the cavity Qs is an ongoing activity as well as the upgrade of the injector linac, housing a waveguide power coupler. First results from this new module are expected in 2010.

REFERENCES

- [1] A. Richter, "Operational Experience at the S-DALINAC", EPAC '96, Sitges (1996) 110.
- [2] K. Alrutz-Ziemssen, D. Flasche, H.-D. Graef., V. Huck, M. Knirsch, W. Lotz, A. Richter, T. Rietdorf, P. Schardt, E. Spamer, A. Stascheck, O. Titze, W. Voigt, H. Wiese and W. Ziegler, „Performance of the Accelerating Cavities at the S-DALINAC”, SRF '89, Tsukuba (1989) 53.
- [3] J. Auerhammer, H. Genz, H.-D. Graef, V. Huck, C. Luetge, A. Richter, T. Rietdorf, P. Schardt, E. Spamer, K. Rühl, A. Stascheck, F. Thomas, O. Titze, J. Toepper and H. Weise, "Latest of the superconducting Darmstadt Electron Accelerator S-DALINAC", SRF '91, Hamburg, (1991) 110.
- [4] J. Auerhammer, R. Eichhorn, H. Genz, H.-D. Graef, R. Hahn, T. Hampel, C. Hofmann, J. Horn, C. Luetge, A. Richter, T. Rietdorf, K. Ruehl, P. Schardt, V. Schlott, E. Spamer, A. Stascheck, A. Stiller, F. Thomas, O. Titze, J. Topper, T. Wesp, H. Weise, M. Wiencken, T. Winkler, "Progress and status of the S-DALINAC", SRF'93, Newport News (1993) 1203.
- [5] M. Kunze, W.F.O. Müller, T. Weiland, M. Brunken, H.-D. Graef, A. Richter, "Electromagnetic design of new rf power couplers for the S-DALINAC", LINAC '04, Luebeck (2004) 736.
- [6] T. Kuerzeder, J. Conrad, R. Eichhorn, J.D. Fuerst, B. Bravo Garcia, H.-D. Graef, C. Liebig, W.F.O. Mueller, A. Richter, F. Schlander, S. Sievers, and T. Weiland, "Injector Upgrade for the superconducting electron accelerator S-DALINAC", Advance in Cryogenic Engineering, (2009), accepted.
- [7] A. Araz, M. Brunken, J. Conrad, H.D. Graef, M. Hertling, F. Hug, M. Konrad, T. Kuerzeder, M. Platz, A. Richter, S. Sievers and T. Weilbach, „Results from a 850 C Heat Treatment and Operational Findings from the 3 GHz SRF Cavities at the S-DALINAC”, SRF '07, Beijing (2007) 163.
- [8] Sahu, B., Chowdhury, G., Ghosh, S., Kanjilal, D., Mathuria, D., Mehta, R., Pandey, A., Patra, P., Rai, A. and Roy, A., "Use of Piezo Actuator to Frequency and Phase Lock a Superconducting Quarter Wave Resonator," in LINAC'08, Vancouver, 2008, in press.